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ROLE OF PLANT GROWTH REGULATORS IN GRAPE PRODUCTION: A REVIEW

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ABSTRACT

Although, India has distinction of achieving highest productivity of grapes among all the grape growing countries of the world but its participation in world trade is very meagre, the reason being non-uniformity in colour, size and TSS in bunch and fewer diameter of berries. This can be solved by efficient water management, nutrient management, canopy management and also by use of Plant Growth Regulators (PGRs). Among these factors, PGRs are more responsive and regulate the productivity and quality in grape. PGRs are very much responsive with a great potential to regulate the growth, productivity and quality of grapes. Therefore, they should be used for specific purpose to get best results. The concentration and stage of application is very crucial, hence little knowledge about these PGRs is essential for the growers. By judicious use of plant growth regulators it will be possible to harvest a crop with greater quantity of export quality produce. This paper reviews the different formulations and applications of PGRs in grape production available at present, as well as the main results of most the past investigations carried out on the topic.

KEYWORDS: Grape, PGRS, NAA, GA, BA, CPPU and Ethylene

INTRODUCTION

Plant Growth Regulators are defined as the organic compounds other than nutrients, which in small amounts promote, inhibit or otherwise modify any plant physiological processes.

[1] Endogenous Plant Growth Regulators

Plant Hormones - these are plant growth regulators, which are synthesized within the plant [endogenously] at a specific site of synthesis and act at a specific site action. They are auxins, gibberellins, cytokinins, abscissic acid, ethylene and brassinosteriods.

Plant Growth Regulators other Than Hormones - these are the growth regulating compounds other than hormones with either growth promoting or inhibiting action. They are polyamines, morph actins, jasmonates, malformins and other groups.

[2] Synthetic Plant Growth Regulators

Growth Promoters, Retardants and Inhibitors – these are exogenously chemically synthesized growth regulating inorganic compounds usually applied at higher concentrations mimic the plant hormonal action. They include all the growth promoting substances, retardants and inhibitors chemical groups.

Methods of Application of Growth Regulators

- Water spray method

- Immersion of plant parts/ dip method
- Lanolin paste method
- Aerosol method
- Vapour method

Formative Effects of Plant Growth Regulators

- Auxins – cell elongation, apical dominance, phototropism, geotropism
- Gibberellins – cell growth (faster cell growth and increased cell elongation), breaks dormancy, fruit set and growth, parthenocarpy [seedlessness]
- Cytokine's – cell division, fruit bud differentiation, fruit growth, bud burst
- Ethylene - Fruit ripening, colour development and structural development
- Abscissic Acid – Reduces impact of stress, triggering bud dormancy, stimulates ripening and senescence
- Brassinosteroids – enhances cell division, cell elongation and protein synthesis
- Growth retardants/inhibitors – checks excessive vegetative growth, improves fruit set and fruit quality

Widely used Plant Growth Regulators in Grape Production

- Auxins – IBA, 4-CPA, NAA (PlanofixTN)
- Gibberellins – GA3
- Cytokinins – 6 BA, PBA, Kinetin, CPPUEthylene – Ethephon / Ethrel (39%)Brassinosteroids – homobrassinolide (CombineTN)
- Growth retardants/inhibitors - Cycocel (CCC) (50%), Maleic Hydrazide (MH), Paclobutrazol (PBZ), Tri Ido Benzoic Acid (TIBA), SADH, Alar etc..
- Others chemicals – bud breaking chemicals such as thiourea, hydrogen cynamide, black bordeaux, dormex etc., Uracil, Xanthine, Caffeine, Ascorbic acid, carbaryl…

Morphological, Physiological and Histological Effects of PGRs

Auxins

Naphthalene acetic acid (NAA)

To overcome the problem of flower and fruit drop

Initiation of berry ripening

Avoid the berry shattering during transport Indole butyric acid (IBA)

Enhances rooting of cuttings and layers

Gibberellic acid

Cell elongation

Stimulation of vine growth

Increase the internodal length of shoots

Elongation of cluster rachis

Elongation of cluster peduncle

Increase the shape and size of berry

Pre-bloom spray increases berry setting

At flowering increases the longitudinal size of berries

After fruit set increase the radial growth of berries

Induction of seedlessness [parthenocarpy]

Cytokinins

6 - Benzyl Adenine (6BA)

Helps in cell division

Improves fruit bud differentiation

Increases carbohydrate production in leaves

Improves berry size and shape

Improves berry weight and quality

CPPU (2 Chloro 4 Pyridyl Phenyl Urea)

Increases the berry size

Increases berry weight by 16 % along with GA3 application

Induce white green colour shining

Peduncle of bunch becomes strong

Quality and freshness of berries retained after harvest

Ethylene

Breaks dormancy

Hastens ripening

Brassinosteroids

Enhances cell division and cell elongation

Increased protein synthesis

Growth retardants / inhibitors

Retards vegetative growth of the plant and internodal length

Increases the photosynthetic rate

Increases the cane and shoot thickness

Increases the endogenous cytokinin: gibberellin ratio

Helps in formation of inflorescence primordia

Growth Regulators in Grape Production

I. Propagation of Vines

- Rooting of cuttingsRooting of air layersBreaking seed dormancy
- Tissue culture

II. Growth and Productivity of Vines

- Termination of bud rest Increasing bud break
- Increasing number of sub canes
- Enhancement of bud fruitfulness and fruit set

III. Quality Improvement

- Enhancement of bunch size and weight
- Production of loose and well-filled clusters
- Induction of seedlessness in seeded varieties
- Thinning of berries
- Improving berry qualities – TSS, sugar-acid ratio, berry crispness and berry adherence, uniform berries (size, shape and colour)
- Regulation of ripening (hastening/ delaying)
- Prevention of post harvest berry drop
- Improving the shelf life of bunches
- Other problems – uneven ripening, shot berries, pink berry…

The use of growth regulators not only enhances the productivity of vines but also helps to produce quality grapes suitable for exports. Choice of growth promoters and regulators to be used depends upon the traits desired in the grapes meant for exports. The effects of various growth regulators and growth promoters are (NRC, Grapes).

Effects of Auxins

Table 1

Growth Concentrations	Regulators	Time of Application	Effects
NAA	20 ppm 15-20 ppm 20-25 ppm	Spraying at berry formation stage. Dipping bunches at sugar formation stage Spraying 10-15 days before harvest.	Controls flower & berry drop. Improves berry luster. Prevents berry drop in transit
IBA	1000-1500 ppm	Dipping of cuttings	Promotes rooting of cuttings
4 CPA	10 ppm	1st spraying when the berry size is 3 mm dia. 2nd spraying when the berry size is 6 mm dia.	Increases the pedicel thickness

Effects of GA

Table 2

Concentrations	Methods of Application	Time of Application	Effects
10-15 ppm	Spraying	Before flowering	Increases the stalk length of the bunch
20-25 ppm 20-25 ppm 20-25 ppm	Spraying Bunch dipping Bunch dipping	After 25% Capfall 50% Capfall 75% Capfall	Thinning of berries Thinning of berries
35-40 ppm	Bunch dipping	After fruit setting	Thinning of bunches
30-40 ppm GA + cytokinin	Bunch dipping	At 3-4 mm berry size	Increases the bunch size.
30-40 ppm GA + cytokinin	Bunch dipping	At 6-7 mm berry size	Increases the bunch size.

Effects of cytokinins

Table 3

<table>
<tr><th>Category</th><th>Concentrations</th><th>Time of Application</th><th>Effects</th></tr>
<tr><td rowspan="3">6 BA</td><td>10 ppm</td><td>15-16 leaf stage after April pruning</td><td>Increases fruit setting in the buds.</td></tr>
<tr><td>10 ppm</td><td>At 3-4 mm berry size along with 30-40 ppm GA after October pruning</td><td>Increases the berry size.</td></tr>
<tr><td>10 ppm</td><td>At 6-7 mm berry size along with 30-40 ppm GA after October pruning</td><td>Increases the berry size and shape.</td></tr>
<tr><td rowspan="2">CPPU</td><td>2 ppm</td><td>1st application at 3-4 mm berry size along with GA dipping</td><td rowspan="2">Increase the stalk thickness & berry size, promotes round berry shape and maintains the green colour of the berries.</td></tr>
<tr><td>2 ppm</td><td>2nd application at 6-7 mm berry size.</td></tr>
</table>

Effects of ethylene

Table 4

Concentrations	Time of Application	Effects
100 ppm	5 days after bud sprout following April pruning.	Reduces apical shoot growth.
200 ppm	At 15-16 leaf stage following April pruning.	Increases the cane thickness.
1000-1500 ppm	3-4 days before October pruning	Induces leaf drop.
250 ppm 4000 ppm	At verasion stage or at sugar formation stage 2 days after pruning	Increases the Brix %. Breaks dormancy.

Effects of Growth Retardants

Cycocel [500 –2000 ppm] or Maleic Hydrazide [500 ppm] or paclobutrazol [3 Kg a.i./ha] at 5leaf stage after April/ back pruning and repeated sprayings effectively reduces shoot vigour and internodal length and also increased fruitfulness of buds besides improving berry quality.

Spraying of homobrassinolide (Combine) @ 1-2 ppm twice at 2-3mm and 5-6mm berry diameter stages enhance the bunch size, berry quality and storability of grapes.

I. Propagation of Vines

For Hardwood cuttings – IBA @ 2000ppm.

For Softwood cuttings – IBA @ 1500ppm.

Root formation in air layers when the shoots treated with 5000 ppm IBA in 50 per cent alcohol solution (Muthukrishnan *et al*., 1960).

Pal *et al.*, (1976) found that Early Muscat seeds showed improved germination, particularly when treated with lower concentrations of 100, 250 or 500 ppm GA3.

II. Growth and Productivity of Vines

1. Termination of Bud Rest

Bud breaking chemicals such as thiourea, hydrogen cynamide, ethephon, potassium nitrate and paclobutrazol have been found to increase bud break.

Swabbing of hydrogen cynamide @ 1.5 % with cotton or sponge to the buds within 48 hrs., after pruning will enhance bud break (Ramteke, 2003).

Pre pruning defoliation with 2.5 % ethephon spray or manually will also help in uniform bud break (Shikhamany, 2006).

2. Increasing Bud Break

More no. of clusters/vine After summer pruning, pinch off the shoots to five nodes at 7-8 leaf stage, one or two buds grow laterally in addition to apical bud. Spraying of 500 to 1000 ppm CCC at 5- leaf stage also increases lateral buds. When these lateral buds reaches 5 leaf stage, one more spray of CCC @ 1000 ppm should be given to check the growth of laterals and apical shoots (Ramteke., 2003).

3. Increasing Number of Sub Canes

Fruitfulness of bud is referred to floral induction. Fruit bud formation takes place during backward/foundation pruning.

Spraying of Uracil @ 50 ppm on the 40th and 50th day after April pruning will increase the fruitfulness of buds by increasing the RNA/DNA ratio and increasing the total nucleic acids content.

Foliar application of 6-BA @ 10 ppm at 45 th day after pruning also increases the bud fruitfulness by increasing the cytokinin/gibberellin ratio (Ramteke., 2003).

More vigour is detrimental to the fruitfulness therefore, CCC is used at 5th leaf stage @ 1000 ppm. Tipping of the shoots can also be done after 9 leaves at 7th leaf. CCC can be again used at 12th leaf stage (7+5) to check the vigorous growth of the shoot (APEDA, 2003).

4. Enhancement of Bud Fruitfulness and Fruit Set

Fruitset is a problem in few grape varieties like Anab-e-Shahi. Spraying of 4-CPA (chlorophenoxy acetic acid) @ 20 ppm five days after full bloom will increase fruit set (Ramteke., 2003).

GA3 at lower concentrations (10-25 ppm) increases fruit set, but at higher concentrations (>50 ppm) it is known to reduce set (Farmahan, 1971).

6-BA and PBA were found to be effective in increasing fruit set and in both seeded and seedless varieties of grapes.

Pre bloom application of SADH at 2000 ppm also increased fruit set in Anab-e-Shahi and CCC @ 1000 ppm for perlette and Thompson Seedless varieties (Armugam and Madhavarao, 1973).

III. Quality Improvement

1. Enhancement of Bunch Size and Weight

The number of berries in bunch and the berry weight mainly determines bunch size. It is berry diameter that is important rather than the berry length or overall size for export of table grapes.

Use of 1 ppm homo-brassinolide together with 30 ppm GA twice after shatter stage have been found to be effective for increasing the diameter of Thompson Seedless to more than 18 mm required for export (Chadha., 2006).

CPPU (N-(2 Chloro- 4 Pyridyl)-N Phenyl Urea), is a synthetic cytokinin like chemical, which was applied on Thompson Seedless grapes at 3-4 and 6-7 mm berry size stage as a dipin 1 ml or 2 ml/L as a single dose and in combination with GA3 @ 40 ppm and was compared with untreated control and found successful in increasing berry size (NRC Grapes. Annual Report., 2005-06).

At 3-4 leaf stage, CCC @ 250 ppm and 6-BA @ 10 ppm to increase the cluster growth. GA3 @ 10 ppm as foliar spray at parrot green stage. After one week GA3 @ 15 ppm as foliar spray for rachis elongation.

2. Production of Loose and Well-Filled Clusters

(Increasing the rachis length and reducing the fruit set)

Number of berries per unit length of the cluster rachis is an indication of the compactness/looseness of the cluster.

A bunch is considered to be well filled, when the number of berries /cm length of the rachis ranges between 3-3.5 depending upon the diameter of the berry.

At 3-4 leaf stage, CCC @ 250 ppm and 6-BA @ 10 ppm can be used to increase cluster growth (APEDA., 2003).

Approximately 90-120 berries are retained per cluster depending upon the number of leaves available to nourish it at 8-10 berries per every leaf depending on its size (Shikhamany-FAO website).

Prebloom (parrot green stage) GA application @ 10-15 ppm to the clusters will increase the rachis length, while GA application @ 30-40 ppm at the initiation of anthesis can reduce the set by its pollenicidal effect.

3. Induction of Seedlessness in Seeded Varieties

The mechanism of induction of seedlessness in seeded varieties is to induce parthenocarpy. GA3, MH, TIBA have pollenicidal effect when applied at pre bloom stages.

In Delaware and other seeded varieties of grapes the application of GA3 at 100 ppm 10 days before anthesis and again two weeks after bloom induced seedlessness and advanced maturity (Krishi and Taski., 1958).

4. Increasing Berry Diameter

To produce spherical or nearly spherical berries in varieties that produce elongated berries, GA application must be avoided during bloom and auxins or cytokinins like substances should be used between 7 and 21 days after full bloom to promote cell division and radical expansion of berries.

4-CPA, BA or brassinosteroids, CPPU in combination with GA can be used for increasing the diameter of berries (Ramteke., 2003).

At berry size of `Bajra’ grain or 3-4 mm diameter.

GA3 @ 40 ppm + CPPU@ 2 ppm (or)

GA3 @ 40 ppm + BR @ 1 ppm (or)

GA3 @ 40 ppm + 6 BA (or) 4-CPA @ 10 ppm

At berry size of `Redgram’ grain or 6-7 mm diameter

GA3 @ 30 ppm + CPPU @ 1 ppm (or)

GA3 @ 30 ppm + BR @ 1 ppm (or)

GA3 @ 30 ppm + 6 BA or 4-CPA @ 10 ppm

5. Improving Berry Qualities – TSS, Sugar-Acid Ratio, Berry Crispness and Berry Adherence, Uniform Berries (Size, Shape and Colour)

Uniformity of berries in a bunch for size, shape and colour are important for table grapes.

The berries at apical end of the bunch are generally smaller therefore, clip off the apical one-third to one-fourth portion of each cluster at full bloom in varieties grown in peninsular India.

Uniformity of colour is a varietal character and is influenced by diurnal variation in temperature. In coloured varieties formation of colour is a problem.

Ethephon application is very effective in enhancing the colour development in almost all the coloured varieties (Ramteke., 2003).

6. Increasing Berry Adherence

Poor adherence of berries to the stalks increases the berry drop during transit and storage.

Berry Drop is of Two Types

- Detachment without a portion of the pedicel attachment to the berry - Wet dropCan be reduced by spraying 100 ppm NAA once 10 days prior to harvest and a gain a week later.
- Breaking of pedicels – Dry drop

Reduced by increasing the pedicel thickness by treating the clusters with 15 ppm 4-CPA or 50 ppm of BA at berry softening stage.

Treating the clusters with Brassinolide @ 1ppm at 3-4 mm and again at 6-7 mm stage of berries can also increase the pedicel thickness (Ramteke., 2003).

7. Increasing Berry Crispness

Crispness of berries can be determined by the firmness of the pulp. It depends on the availability of source in relation to sink (leaf/fruit ratio) translocation of photosynthates into the berry (sink capacity).

Practices like GA treatment of berries increase the translocation of photosynthates into the berry. Application of ethephon at verasion reduces the firmness of berries in Thompson Seedless (Ramteke., 2003).

8. Increasing TSS and Sugar Acid Ratio

Bloom time sprays of 10 ppm 4-CPA or 10 ppm NAA increase T.S.S. content of berries at harvest.

Pre-bloom or bloom time application of GA @ 15-40 ppm can increase the T.S.S. content by reducing the number of berries in a cluster.

On the other hand post bloom sprays with GA reduce the T.S.S content as a result of increase in size.

Among all growth substances, ethrel is the most effective chemical in increasing the T.S.S.content in many coloured varieties of grape (Ramteke, 2003).

9. Regulation of Ripening (Hastening/ Delaying)

In North India to save the grapes from cracking and rotting due to rains during ripening period, pre- bloom application of GA @ 10-15 ppm can hasten the ripening by reducing the number of berries in a bunch.

Application of ethephon @ 250 ppm during 10-15 days after set is most effective in hastening the ripening (Ramteke, 2003).

Fruit ripening can also be enhanced by by few days with the spray of 600 ppm ethephon at colour break stage. It helps in improving fruit quality (Dhillon, 2006). Application of GA at 2 to 3 weeks after berry set can delay ripening of berries by increasing their size.

10. Post Harvest Berry Drop and Shelf Life

Retaining green colour of berries Treating the berries with CPPU @ 2ppm at 3-4 mm size (‘Bajra’ grain stage) and again at 6-7 mm size (‘Red gram’ grain stage) may also be helpful to retain the green colour of berries at harvest (APEDA, 2003).

6-BA is also used @ 10 ppm at berry softening stage i.e. about one month prior to harvest in order to retain the green colour of the berries (APEDA, 2003)

NAA @ 100 ppm one week prior to harvest will reduce the post harvest berry drop (APEDA, 2003).

Improving shelf life - Calcium nitrate @ 1 % dipping NAA @ 100 ppm one week prior to harvest.

11. Other Problems

To reduce the shot berry formation in Gulabi, application of 50 ppm of gibberellic acid solution (50 mg/l of water) to the panicles at 5-6 days after full bloom is recommended.

The perlette variety faces the problem of uneven berry ripening which can be effectively solved with the spray of ethephon @ 400 ppm a.I., at colour break stage (Dhillon, 2006).

Uneven ripening in coloured seedless varieties like Flame Seedless and Beauty Seedless could be reduced to a great extent by foliar sprays of ethephon at 400 ppm at colour break stage. The problem of hormonal residues in grape berries, however, needs to be looked into (Chadha, 2006).

Excess gibberellic acid application in grapes is known to have adverse effects like,

- Increase auxin levels in vine.
- Residual conc. should not be more than 0.015 ppm.
- Unfruitfulness.
- Stickiness of peduncle and rachis.
- Delays maturity and reduces the shelf life.
- Thick skin of berries.
- Berry shedding during transport.

FINAL CONCLUSIONS

PGRs are very much responsive with a great potential to regulate the growth, productivity and quality of grapes.

Therefore, they should be used for specific purpose to get best results. The concentration and stage of application is very crucial, hence little knowledge about these PGRs is essential for the growers.

By judicious use of plant growth regulators it will be possible to harvest a crop with greater quantity of export quality produce.

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